



# Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing

May 18, 2010

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Seismicity and Reservoir Fracture Characterization

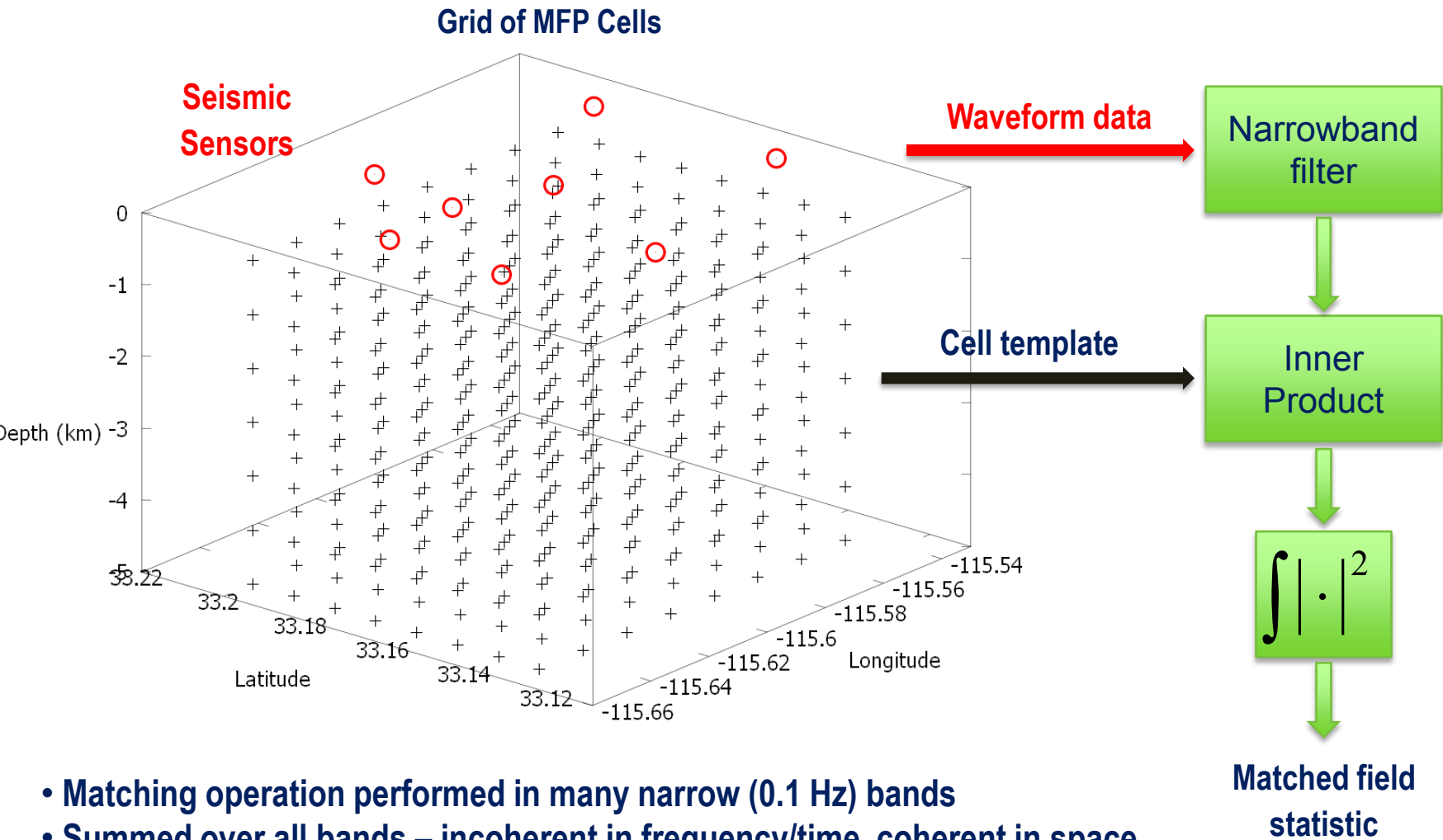
- Timeline
  - Project start and end dates: October 2009 – September 2012
  - Percent complete: 15%
- Budget
  - Total project funding: \$925,000
  - DOE share: \$925,000
  - Awardee share: \$925,000
  - Funding received in FY09: \$0
  - Funding received in FY10: \$925,000
- Barriers
  - Images of Fractures After Stimulation
    - Inability to characterize the physical parameters of potential EGS reservoirs after stimulation
- Partners
  - None

- The objective of this project is to detect and locate more microearthquakes observed during EGS operations using the matched field processing (MFP) technique
  - Conventional earthquake location techniques are labor-intensive, poorly suited to rapid turnaround situations, and may miss events if many individual earthquake recordings overlap (e.g., during fluid injection operations)
- This project will advance EGS passive microseismic technique technologies by enhancing the ability to map microearthquakes in a variety of traditionally difficult situations
  - Aid in reservoir validation and sustainability studies
- Our project will focus on two variants of MFP
  - Empirical MFP is best suited to detect earthquakes in areas with abundant previous seismicity
  - Model-based MFP can be applied to areas with little or no previous seismicity

- Our MFP technique is an adaptation of a signal-processing technique originally developed to locate continuous underwater acoustic sources
- Current project will modify the MFP technique to specifically detect and locate microearthquakes in geothermal reservoirs using seismic data at local distance

FY09 – FY10 Milestones	Go / No-Go Decision	Status
Milestone 1: Obtain seismic data	Obtain acceptable data	COMPLETED
Milestone 2: Obtain earthquake catalog	Obtain or create appropriate catalog	COMPLETED*
Milestone 3: Create master matching templates	Successful creation of a network of master templates	In progress

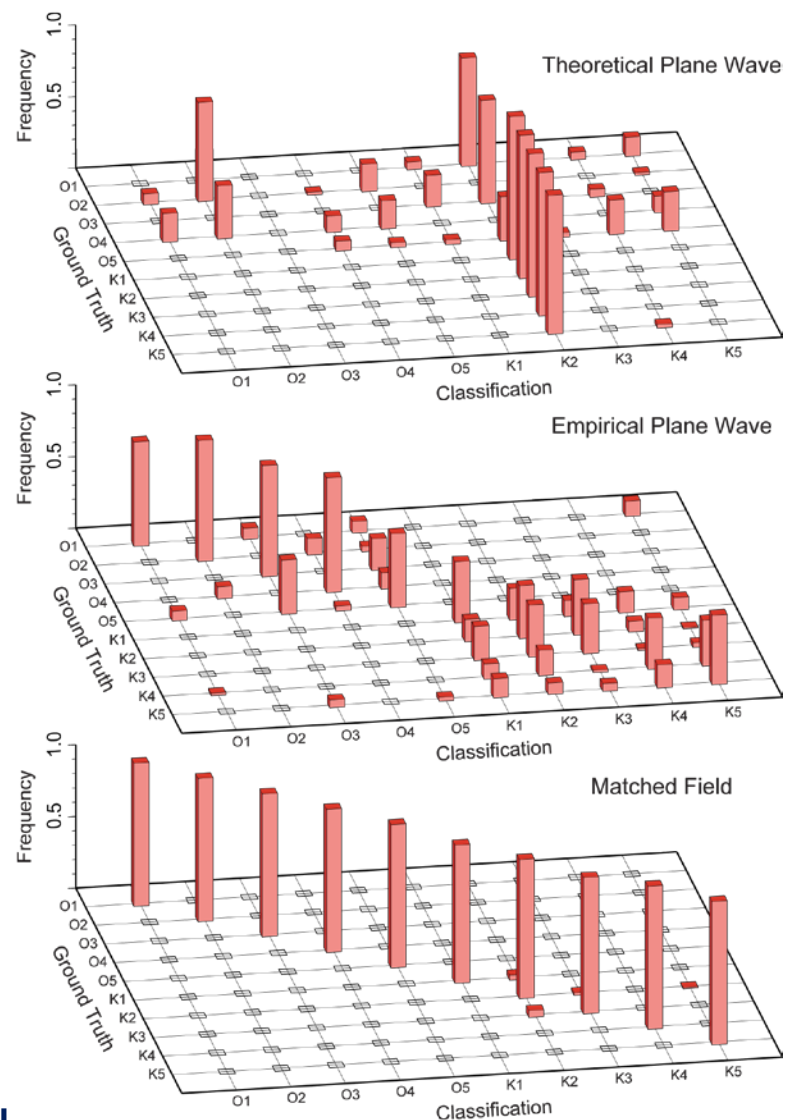
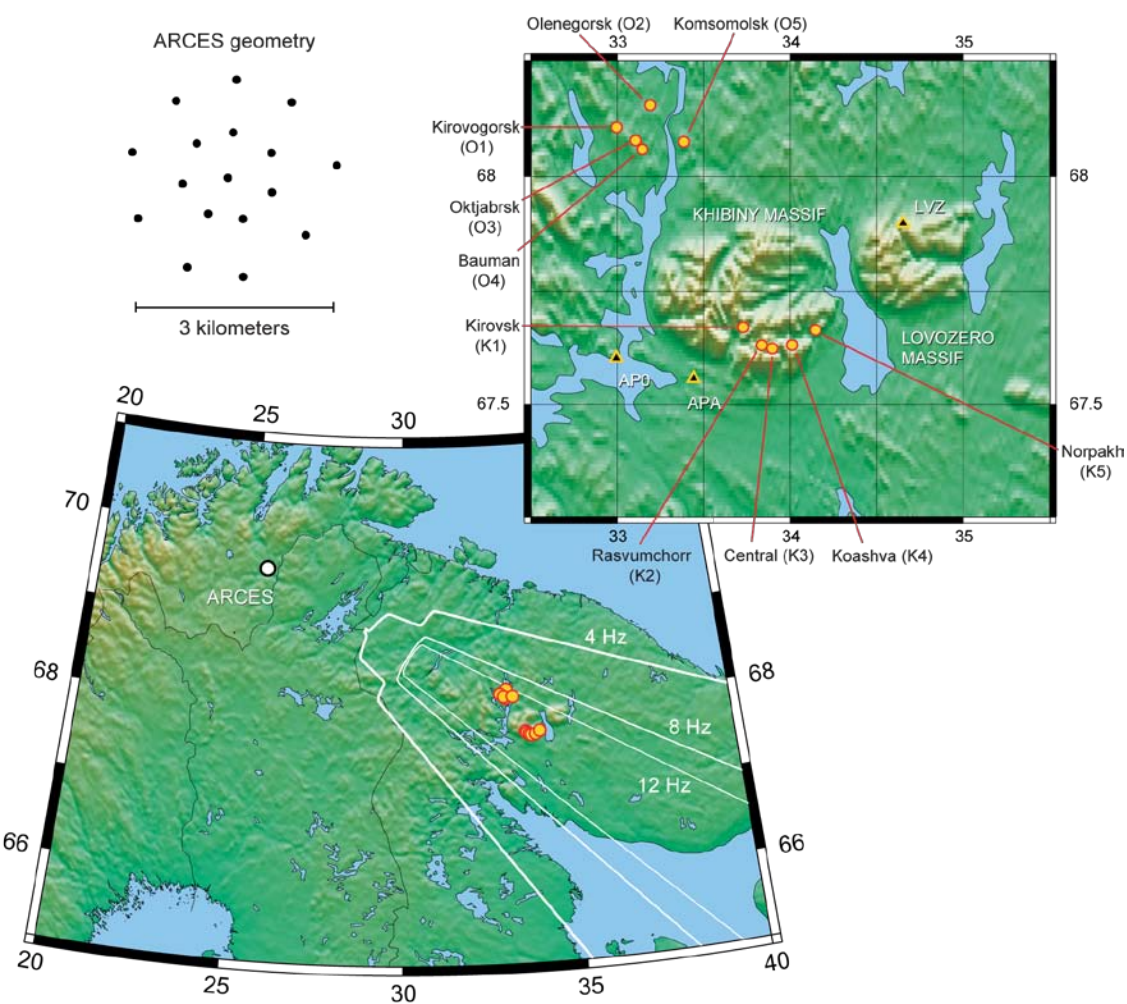
# Matched Field Processing is an underwater sound method adapted to seismic problems



- Matching operation performed in many narrow (0.1 Hz) bands
- Summed over all bands – incoherent in frequency/time, coherent in space
- Templates developed empirically or by forward calculation through a geophysical model



# The technique already has shown potential in mapping regional events



**Harris & Kvaerna (2010), Superresolution with seismic arrays using empirical matched field processing, submitted to GJI**

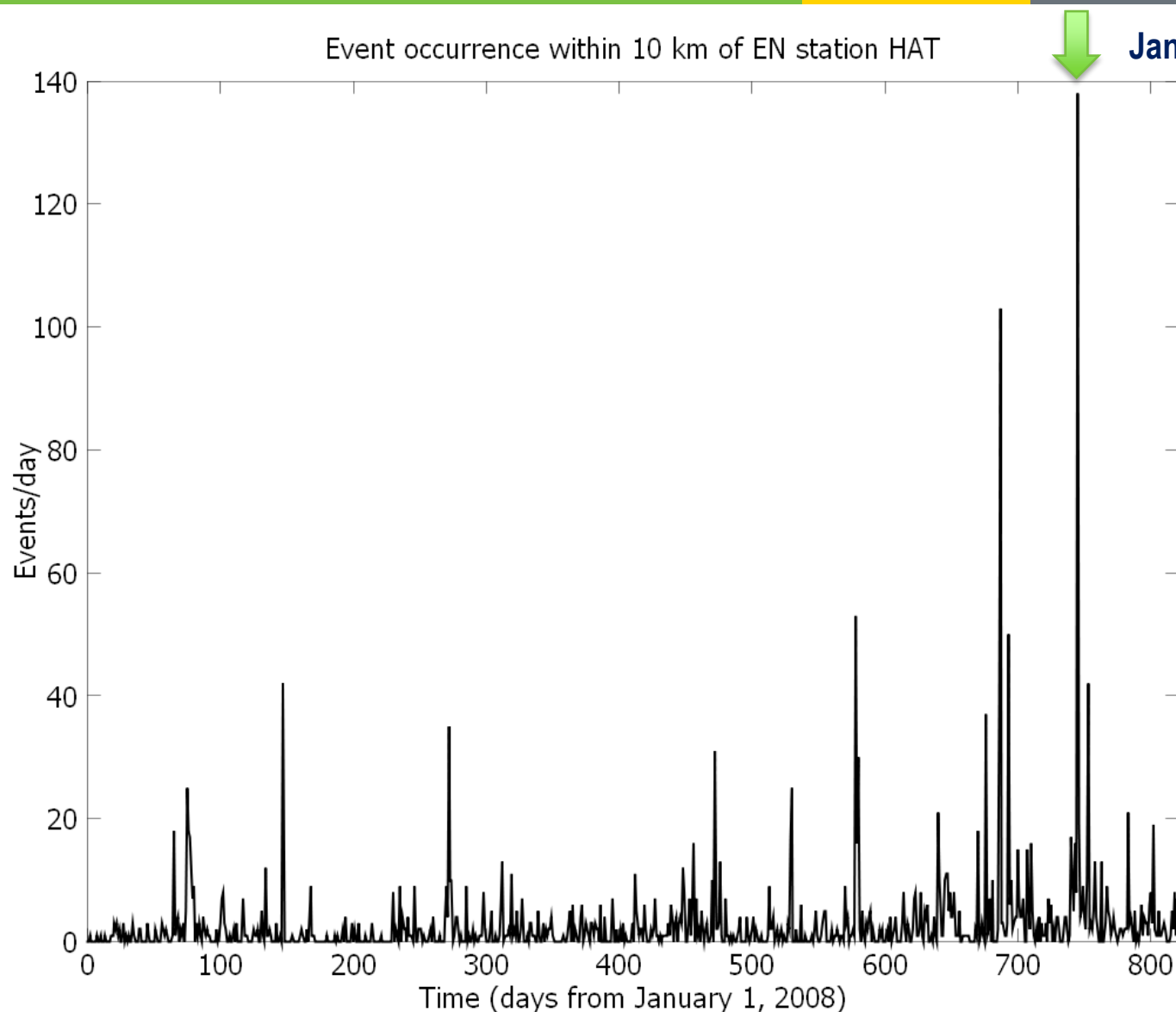
## Progress to Date

- Initial Matlab implementation of a matched field processor completed
- Seismic data and earthquake catalog acquired for the Salton Sea geothermal field
- Initial processing conducted for a sampling of template events from a probable tectonic sequence

## Next steps, expected outcomes

- Double-difference relocation of sequence events
- Determine what MFP statistic is sensitive to:
  - Proximity of seismicity to template events
  - Mechanism
- If sensitive principally to proximity, then continuous seismicity mapping is the outcome

# We are focusing our efforts on the Salton Sea geothermal field



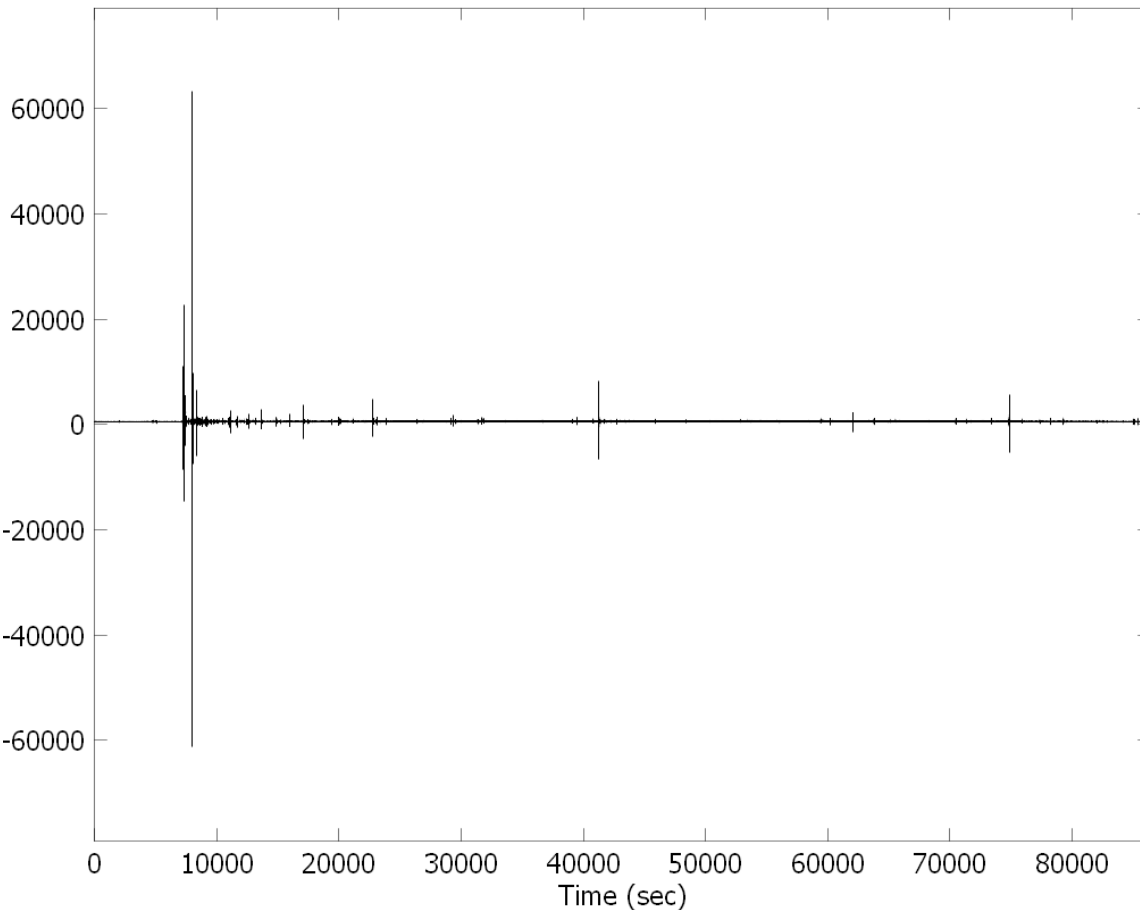
January 15, 2010

**SCEDC catalog**



# We chose the January 15 swarm to test our initial Matched Field code

HAT vertical component - January 15, 2010

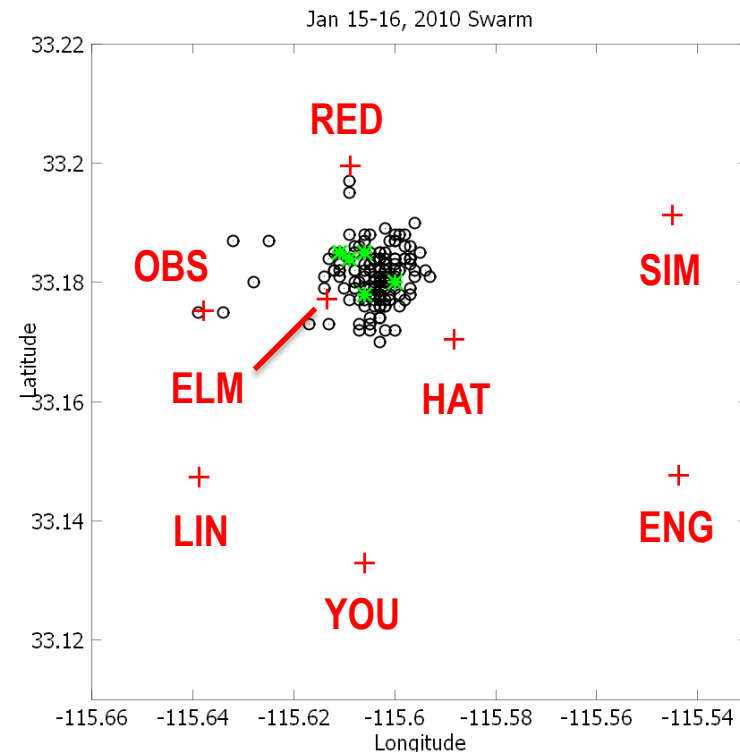


## SCEDC catalog

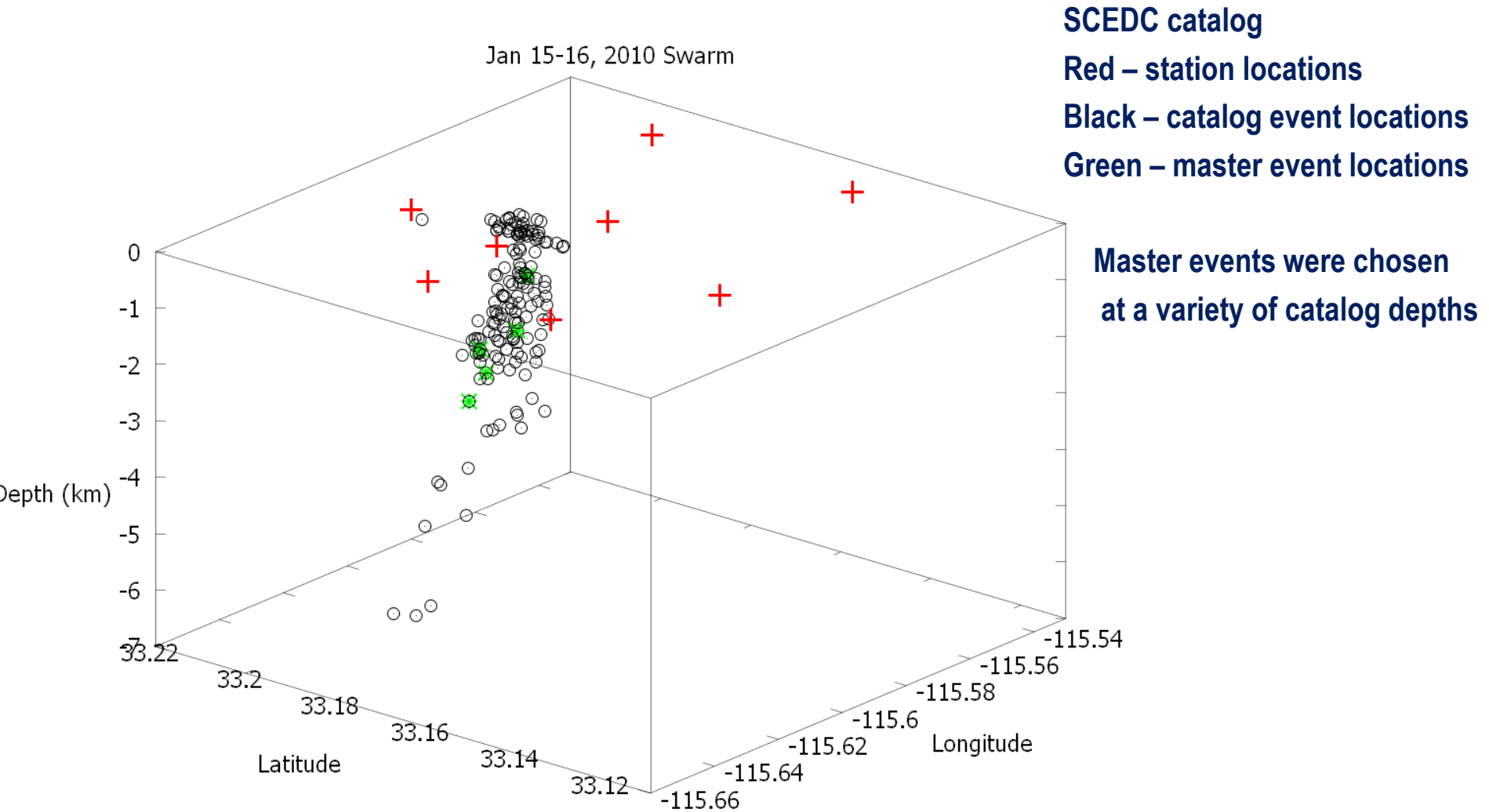
Red – station locations

Black – catalog event locations

Green – master event locations

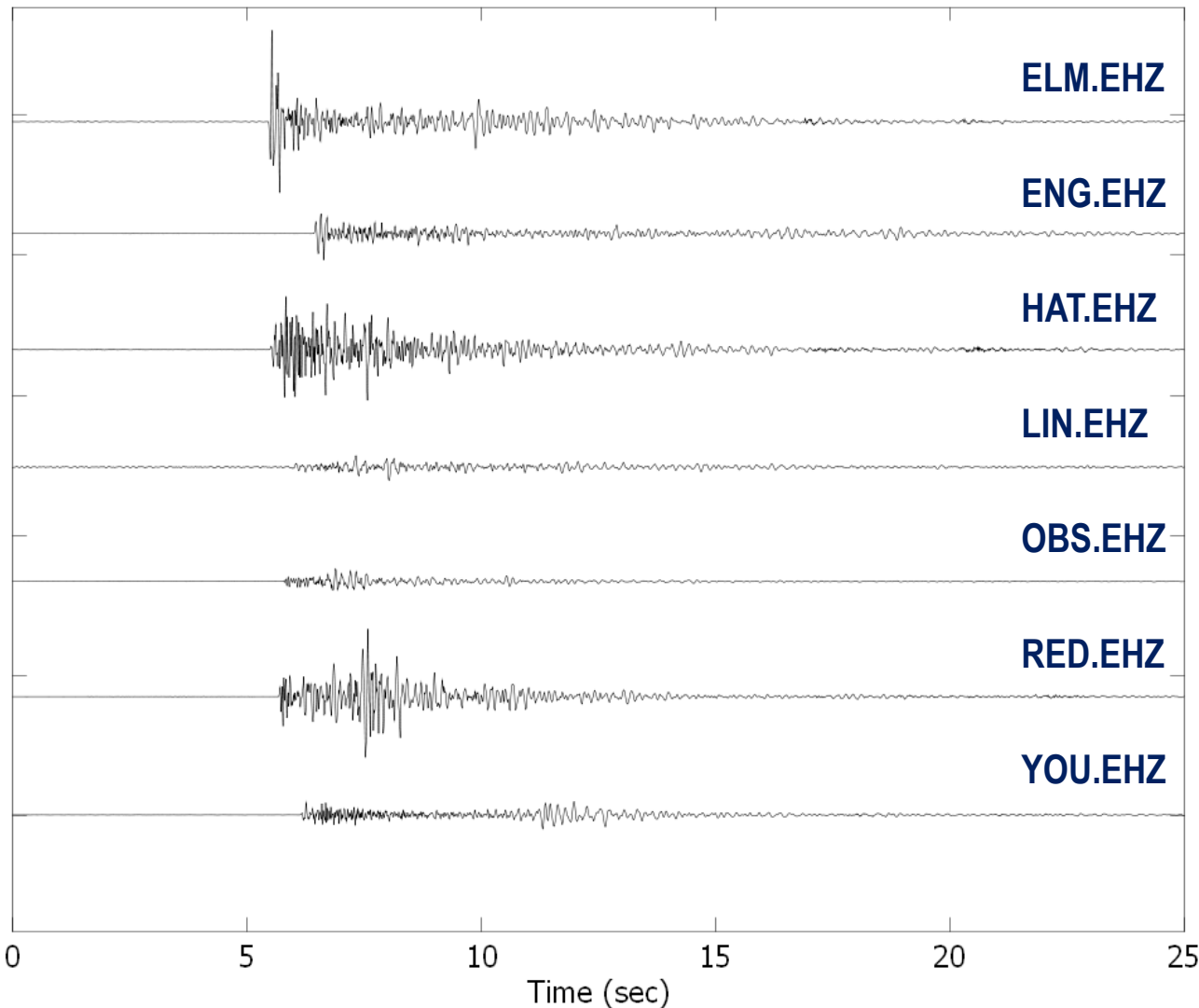


# Events were located approximately in a vertical column



# Master events are used to develop templates then applied to a data stream

2010/01/15 11:27:48.46 mag 2.04 33.185 -115.611 depth 3.0



**Desired characteristics:**

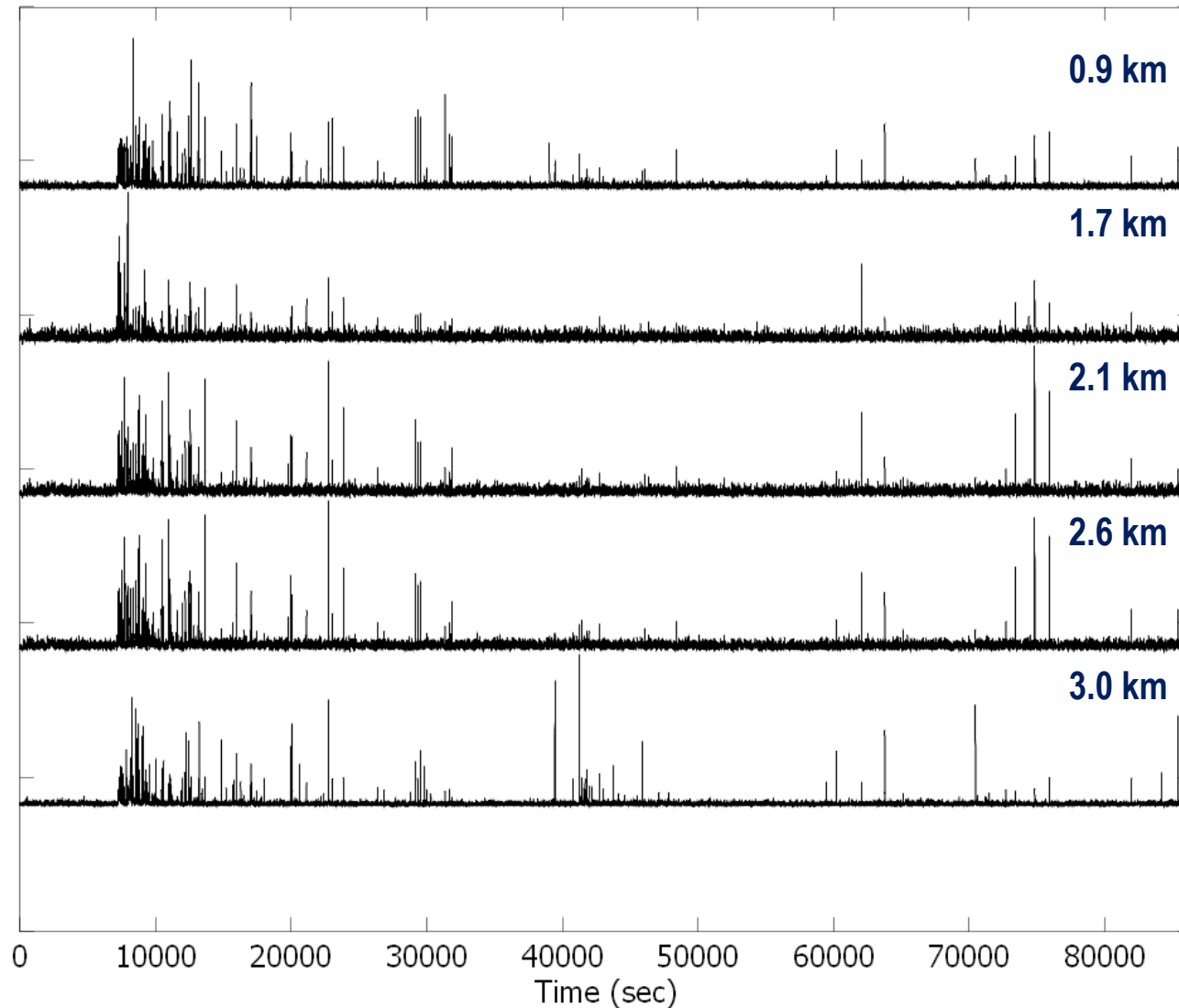
**High SNR**

**Single, non-overlapped events**

**Sampling the mapping volume  
uniformly**

# Initial results suggest MFP captures more than the catalog seismicity

Matched field statistics



**2 – 5 Hz band**

**Now the real work begins:  
interpretation**

**MF statistics sensitive to  
location?  
mechanism?**

**Resolution?**

**Higher frequencies?**

- FY10

Scientific Labor	0.49 FTE
Postdoc Labor	0.17 FTE
Administrative Support	0.02 FTE
Conferences	6K
Computers & Software	20K
Procurements – Scientific	108K (Lien)

- FY11

Scientific Labor	0.52 FTE
Postdoc Labor	0.80 FTE
Administrative Support	0.04 FTE
Conferences	10K

- FY12

Scientific Labor	0.35 FTE
Postdoc Labor	0.67 FTE
Administrative Support	0.04 FTE
Conferences	10K

- Complete empirical MFP study during FY10 and FY11:
  - Milestone 2: Relocate catalog earthquakes
  - Milestone 3: Finish developing a catalog of master matching templates using the empirical MFP technique
  - Milestone 4: Finalize the empirical MFP code for use on a continuous seismic datastream using the previously calculated master templates
  - Milestone 5: Model Coulomb stress changes due to an opening crack which would be consistent with observed seismicity
- We have successfully passed the first decision point
  - Results of initial study showed that empirical MFP identified more microearthquakes than in the original catalog
- Perform initial study of model-based MFP during FY12



- This project will advance EGS Passive Microseismic technology used during reservoir validation and sustainability studies
- Initial studies show that MFP can detect and locate more microearthquakes than traditional earthquake location techniques
- MFP can potentially be applied in real-time
- Project will explore two variants of MFP
  - Empirical MFP can automatically map large numbers of events once a modest number of training events are located manually
  - Model-based MFP should detect and locate earthquakes where little or no previous seismicity existed (e.g., when growing fractures during hydraulic fracturing operations)